Electronic Version
Stylesheet Version v1.1.1

Claims

[c1] What is claimed is:

A logging tool, comprising:

a tool body;

a simple transmitter comprising a single antenna disposed on the tool body;

four simple receivers, each comprising a single antenna, disposed on the tool body and spaced apart from the simple transmitter to form four arrays; and

an electronic module for controlling operation of the four arrays,

wherein the simple transmitter is configured to generate a magnetic field having a transverse component,

wherein each of the four simple receivers is sensitive to the magnetic field generated by the simple transmitter, and at least one of the four simple receivers is sensitive to the transverse component of the magnetic field generated by the simple transmitter, and

wherein the four arrays are configured to provide measurements at at least three depths of investigation.

[c2] The logging tool of claim 1, wherein the simple transmitter is configured to operate at a frequency ranging

from about 5 KHz to about 200 KHz.

[c3] The logging tool of claim 1, wherein the simple transmitter is configured to operate at two frequencies.

[c4] The logging tool of claim 3, wherein the two frequencies are about 13 KHz and about 26 KHz.

[c5] The logging tool of claim 1, wherein the electronic module includes a program having instructions for determining at least one formation parameter.

[c6] The logging tool of claim 5, wherein the at least one formation parameter comprises at least one selected from an invasion radius, an invaded zone resistivity, and a formation resistivity.

[c7] The logging tool of claim 1, further comprising four bucking coils configured to reduce mutual couplings in the four arrays.

[c8] The logging tool of claim 7, wherein at least one of the four bucking coils is co-wound with at least one of the four simple receivers.

[c9] The logging tool of claim 1, wherein the simple transmitter comprises a tilted antenna.

[c10] The logging tool of claim 11, wherein one of the four

simple receivers comprises a tilted antenna orientated in a direction not orthogonal to a direction of the tilted antenna of the simple transmitter.

[c11] A logging tool, comprising:
a tool body;
a transmitter comprising two antennas disposed on the tool body, wherein the two antennas are arranged in different orientations;
two simple receivers, each comprising a single antenna, disposed on the tool body and spaced apart from the transmitter;
a third receiver, comprising two antennas, disposed on the tool body and spaced apart from the transmitter and the two simple receivers; and
an electronic module for controlling operation of four arrays formed by the transmitter and the two simple receivers and the third receiver,
wherein at least one of the two antennas in the transmitter is configured to generate a magnetic field having a transverse component,
wherein at least one of the two antennas in the third receiver is responsive to the transverse component of the magnetic field generated by the transmitter, and
wherein the four arrays are configured to provide measurements at at least three depths of investigation.

[c12] The logging tool of claim 11, wherein the transmitter is configured to operate at a frequency ranging from about 5 KHz to about 200 KHz.

[c13] The logging tool of claim 11, wherein the transmitter is configured to operate at two frequencies.

[c14] The logging tool of claim 13, wherein the two frequencies are about 13 KHz and about 26 KHz.

[c15] The logging tool of claim 11, wherein the electronic module includes a program having instructions for determining at least one formation parameter.

[c16] The logging tool of claim 15, wherein the at least one formation parameter comprises at least one selected from an invasion radius, an invaded zone resistivity, and a formation resistivity.

[c17] The logging tool of claim 11, further comprising four bucking coils to reduce mutual couplings in the four arrays.

[c18] The logging tool of claim 17, wherein at least one of the four bucking coils is co-wound with at least one antenna selected from the two simple receivers and the two antennas in the third receiver.

[c19] A logging tool, comprising:

a tool body;

a transmitter comprising three antennas disposed on the tool body, wherein the three antennas are arranged in three different directions;

two simple receivers, each comprising a single antenna, disposed on the tool body, wherein each of the two simple receivers is spaced apart from the transmitter;

a third receiver disposed on the tool body and spaced apart from the transmitter and the two simple receivers, wherein the third receiver comprises three antennas arrange in three directions substantially identical to the three different directions of the three antennas of the transmitter; and

an electronic module for controlling operation of the transmitter, the two simple receivers, and the third receiver,

wherein arrays formed by the transmitter and the two simple receivers and the third receiver are configured to provide measurements at at least three depths of investigation.

[c20] The logging tool of claim 19, wherein the transmitter is configured to operate at a frequency ranging from about 5 KHz to about 200 KHz.

[c21] The logging tool of claim 19, wherein the transmitter is configured to operate at two frequencies.

[c22] The logging tool of claim 21, wherein the two frequencies are about 13 KHz and about 26 KHz.

[c23] The logging tool of claim 19, wherein the electronic module includes a program having instructions for determining at least one formation parameter.

[c24] The logging tool of claim 23, wherein the at least one formation parameter comprises at least one selected from an invasion radius, an invaded zone resistivity, and a formation resistivity.

[c25] The logging tool of claim 19, further comprising five bucking coils for reducing mutual couplings in the two simple receivers and the three antennas in the third receiver.

[c26] The logging tool of claim 25, wherein at least one bucking coil is co-wound with at least one antenna selected from the two simple receivers and the three antennas in the third receiver.

[c27] The logging tool of claim 19, wherein the three different directions of the antennas of the transmitter are substantially orthogonal to each other.

[c28] A logging tool, comprising:
a tool body;
a transmitter disposed on the tool body, wherein the transmitter is configured to generate a magnetic field having a transverse component;
four receivers disposed on the tool body and spaced apart from the transmitter; and
an electronic module for controlling operation of the transmitter and the four receivers,
wherein each of the four receivers is responsive to the magnetic field generated by the transmitter,
wherein at least one of the four receivers is responsive to the transverse component of the magnetic field generated by the transmitter, and
wherein arrays formed by the transmitter and the four receivers provides at least three depths of investigation.

[c29] The logging tool of claim 28, wherein the transmitter comprises two antennas arranged in two different directions, one of the four receivers comprises two antennas arranged in directions substantially identical to the two different directions of the two antennas in the transmitter.

[c30] The logging tool of claim 28, wherein the transmitter comprises a triaxial transmitter, one of the four receivers

comprises a triaxial receiver.

[c31] A logging tool, comprising:

a tool body;

a transmitter disposed on the tool body, wherein the transmitter is configured to generate a magnetic field having a transverse component;

an electrode disposed on the tool body and spaced apart from the transmitter;

three receivers disposed on the tool body and spaced apart from the transmitter and the electrode; and

an electronic module for controlling operation of the transmitter, the electrode, and the three receivers,

wherein arrays formed by the transmitter and the three receivers provide at least two depths of investigation, and

wherein at least one of the three receivers is responsive to the transverse component of the magnetic field generated by the transmitter.

[c32] A logging tool, comprising:

a tool body;

a transmitter disposed on the tool body, wherein the transmitter is configured to generate a magnetic field having a transverse component;

two electrodes disposed on the tool body and spaced apart from each other and from the transmitter;

two receivers disposed on the tool body and spaced apart from the transmitter and the two electrodes; and an electronic module for controlling operation of the transmitter, the two electrodes, and the two receivers, wherein at least one of the two receivers is responsive to the transverse component of the magnetic field generated by the transmitter.

[c33] A logging tool, comprising:
a tool body;
a transmitter disposed on the tool body, wherein the transmitter is configured to generate a magnetic field having a transverse component;
three electrodes disposed on the tool body and spaced apart from each other and from the transmitter;
one receivers disposed on the tool body and spaced apart from the transmitter and the three electrodes; and
an electronic module for controlling operation of the transmitter, the three electrodes, and the receiver, wherein the receiver is responsive to the transverse component of the magnetic field generated by the transmitter.

[c34] A logging tool, comprising:
a tool body;
a transmitter disposed on the tool body, wherein the transmitter is configured to generate a magnetic field

having a transverse component;
two receivers disposed on the tool body spaced apart from the transmitter; and
an electronic module for controlling operation of the transmitter and the two receivers,
wherein the transmitter is configured to operate at different frequencies to provide measurements at different depths of investigation, and
wherein at least one of the two receivers is responsive to the transverse component of the magnetic field generated by the transmitter.

[c35] A method for well logging, comprising:
disposing a logging tool in a borehole penetrating a formation;
obtaining a plurality of measurements of formation resistivity, wherein the plurality of measurements cover at least three different depths of investigation and at least one of the plurality of measurements is sensitive to formation anisotropy; and
determining an electrical property of the formation based on the plurality of measurements.

[c36] The method of claim 35, wherein the electrical property of the formation comprises one selected from an invaded zone resistivity, an un-invaded zone resistivity, and the formation anisotropy.

[c37] The method of claim 36, wherein the invaded zone resistivity comprises a horizontal resistivity and a vertical resistivity.

[c38] The method of claim 36, wherein the un-invaded zone resistivity comprises a horizontal resistivity and a vertical resistivity.

[c39] The method of claim 35, wherein the plurality of measurements comprise at least one galvanic measurement.

[c40] The method of claim 35, wherein the determining the invasion profile uses a formation model selected from a 1D model, a 1D+1D model, a 2D model, and a 3D model.